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A market-based approach to marine sand resource management in the Pearl River estuary, China

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ABSTRACT

The Pearl River estuary is a microcosm of marine sand resource management issues, which are being experienced in many developing coastal regions in China. The increasing demand and inefficient management of marine sand have resulted in a series of environmental problems and raised great challenges for rational utilization of marine sand. In the long term, resolving management conflicts and improving the efficiency of resource utilization will require a shift in management approach from administrative examination and approval (AEA) of sector-based management to market-based approach of cooperation management. This paper concerns a pilot scheme for market-based resource allocation, and illustrates how the involved agencies could work together to push forward the scheme in a sectoral context. Both achievements and inadequacies of the scheme are presented, and enabling factors are identified, which include administrative authorization, institutional support and approach improvement, which facilitate the success of the scheme. We also describe key elements (a clearly defined exchange object, independent third-party trade platform and standardized market rules, rational goals, and cooperation mechanism), which are essential for a market-based approach to manage marine sand. We hope the experience acquired in the Pearl River estuary will be useful for other coastal regions in the world.

1. Introduction

Marine sand and gravel deposits are widely used in the construction industry, coastal reclamation and beach nourishment (Hanson et al., 2002; Harrison, 2003; Highley et al., 2007). Along with exhausting land-based sand sources and increasing environmental pressure, offshore sand sources now contribute significantly to the overall provision of sand materials in many countries. Marine sand mining has become the second most important marine mining activity after oil extraction (Cho, 2006; Zhang, 2003). Today, annual global production of the aggregate is about 16.5 billion tons, of which approximately 10% is supplied by marine sand mining in coastal waters (William et al., 2004).

Marine sand is one of the most important marine resources in the Pearl River estuary. In order to meet the intensive demand of many coastal reclamation projects and infrastructure constructions in the Pearl River Delta, sand mining activities have expanded rapidly since the 1980s. In the last 30 years, more than 0.55×10^9 m^3 of sand and gravel has been mined from the Pearl River estuary and the production may increase further to supply the materials needed for the construction of the planned projects in the coming years (Ji et al., 2009) .[1] Marine sand is limited in quantity and should be managed efficiently. The United Kingdom has one of the largest marine aggregate industries in Europe and in the world because of its large marine sand resources. In order to make a rational use of marine sand, the market mechanism in the UK has been fully exercised with a well-organized administrative regime, clearly defined jurisdiction and perfect legal framework. Operators must pay a royalty to The Crown Estate for every ton of dredged from licenses (Cao and Hu, 2008; Highley et al., 2007; Yin, 2004). As one of the earliest countries to exploit marine sand, the

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[1] All the statistical data presented in this paper exclude Hong Kong and Macau Special Administrative Regions.

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Netherlands has established a strict control system including planning, permission, prospecting, extraction, processing, and monitoring for its sand dredging industry. Both resource compensation and ecosystem impact assessment play critical roles in managing sand resource (Cao, 2007; Harrison, 2003; Meulen et al., 2005; Yang et al., 2014). The peak period of exploitation in Japan was reached in 2000 when the annual requirements for all projects were about 91.0×10^6 m^3 (Chen and Hu, 2005). Extensive and unplanned marine sand mining exacerbated the burden of the coastal environment in Japan. In response to the environmental problems, some counties in Japan began to enact laws to prohibit nearshore sand mining and exercise control over total exploitation quantity from 1998. Coordination mechanisms among coastal governments had been established for coastal environmental protection at both national level and local level. Now, the sand dredging industry in Japan is strictly controlled to avoid environmental damage (Li, 2006; Shen, 2013). In the Pearl River estuary, however, the marine sand exploration activity was often chaotic and excessive, and illegal sand mining occurred frequently (Li, 2011). Environmental issues and accidents (including saltwater intrusion, coastal erosion, degradation of fishery resources, and broken seabed pipelines) have emerged (Tang et al., 2011). Similar problems with marine sand management are being experienced in other developing coastal regions in China. The current sector-based approach of Administrative Examination and Approval (AEA) originated during the planned economy period of 1953–1992, and the management suffered from a lack of coordination and economic incentives. Using a market-based approach to allocate natural resources, which has been accepted as an effective approach in developed countries (Adonis et al., 2010; Wang, 1999), is now being introduced in China. The State Oceanic Administration (SOA) has initiated a pilot scheme to auction sand mining sea-area-use rights in the Pearl River estuary since 2007.

In this paper, we first give a brief introduction to the marine sand mining situation in the Pearl River estuary and assess current marine sand management issues in the area. We then show how the relevant administrative agencies responded to these issues and cooperated to push forward the pilot scheme in a sectoral context. Both achievements and inadequacies of the scheme are presented, along with the measures that are being developed by government departments in an effort to solve these problems. Significant changes are summarized, and the enabling factors that facilitated the success of the scheme are identified. The key elements that are essential for a market-based approach are described, which include a clearly defined exchange object, independent third-party trade platform and standardized market rules, rational goals, and cooperation mechanism. The experience acquired in the Pearl River estuary could foster flexible management alternatives and should be shared with the domestic and international marine communities.

2. Marine sand mining in the Pearl River estuary

2.1. Activities of marine sand mining

The Pearl River is the third largest river in China. It has a catchment area of 453 690 km^2, a length of 2214 km, an annual runoff of 0.33×10^{12} m^3, and an annual sediment runoff of 70.98×10^6 t (Wu et al., 2006). The estuary is located on the mid-southern coast of Guangdong Province, and is composed of the Lingdingyang estuary in the east, the Modaomen waters in the west and the Wanshan Islands' waters in the south. It is bounded to the north by Humen, to the southeast by the boundary of the Hong Kong territorial waters and to the south by the isobaths of about 20 m. The estuary covers an area of approximately 3000 km^2, with the water depth ranging from 5 to 20 m. The total length of its coastline is approximately 220 km (Fig. 1). Recent study by Zhang et al. (2010) showed that the tentative estimation of buried marine sand reserves is about 1.25×10^9 m^3, which is distributed at 20 sites in the estuary.

Since the late 1980s, there has been a steady increase in the demand for sand in the Pearl River Delta because of massive reclamation projects including new airports, buildings, apartments, seaports, roads, and other infrastructures (Chen and Hu, 2005). About 60% of sand used is supplied by marine sand mined. This percentage is expected to increase as river sand is increasingly depleted and environmental regulations on mining in rivers become stricter (Zhang et al., 2010). According to Wang et al. (2003), approximately 0.27×10^9 m^3 marine sand was exploited from the estuary waters between 1985 and 1999. The total marine sand exploited was 48.0×10^6 m^3 in 2001, but declined to 13.80×10^6 m^3 in 2005. By 2010, however, the total amount increased to 30.5×10^6 m^3 (Table 1). In addition, the supply and demand of marine sand remain unbalanced. For example, the total demand for marine sand was about 40.0×10^6 m^3 in 2010, while only 30.5×10^6 m^3 marine sand was supplied. It was estimated that the annual demand for marine sand during 2011–2015 would be over 55.0×10^6 m^3 per year because several major projects will require large amounts of sand, including the Hong Kong-Zhuhai-Macau Bridge, Hengqin New Area Reclamation, Macao New Area Reclamation, and Nansha New Area Reclamation. Considering the reserves of marine sand in the estuary, the maximum period of mining would only be about 40 years if the present consumption rate of sand continued.

The Pearl River estuary is a vital nursery area for some inshore and offshore fish species, and is ecologically and physically sensitive to marine sand mining activity. Marine nature reserves for the Chinese white dolphin (*Sousa chinensis chinensis*), mangroves and birds are located in the offshore area of the estuary. There are also offshore aquaculture areas, major seaports, deep-water navigation channels, and seabed cables. Therefore, marine sand must be exploited in a planned and orderly way to ensure the safety of ecosystems and properties. Until recently, a long-term plan for marine sand mining had not been enacted. Thus, there was a lack of a unified plan about where, when and how much marine sand can be exploited. Most exploitation sites are located in the upper part of the estuary, and approximately 90% of marine sand has been mined in near-shore areas.

Marine sand is limited in quantity and should be managed carefully. In the Pearl River estuary, however, the marine sand exploration activity was usually chaotic and excessive, and illegal sand mining occurred frequently. For example, in just one month of May 2007, the Administration of Ocean and Fisheries of Guangdong Province (AOFGP) handled 46 illegal marine sand mining cases in the Pearl River estuary. These illegal cases included mining without permit, mining in areas other than permitted, mining excessively or not in accordance with approved operating procedures. Of these illegal cases, approximately 90% were unlicensed mining (Li, 2011). The Pearl River estuary is currently facing a growing number of environmental problems (e.g., saltwater intrusion and coastal erosion) and accidents (e.g., damage to seabed pipeline), which are presumed to be caused by sand mining (Han et al., 2010; Ji et al., 2009; Li et al., 2011; Qi and Bao, 2009; Sun et al., 2010). Illegal sand mining not only harms the environment but also supplies sand at lower than market prices, which increases the demand of total marine sand. From 2001 to 2005, the per capita consumption of marine sand in the Pearl River Delta was 1.02 m^3, which is smaller than the 1.79 m^3 in the Netherland, but much larger than the 0.09 m^3 in Germany and the 0.22 m^3 in the UK (calculated according to Adonis et al., 2010).

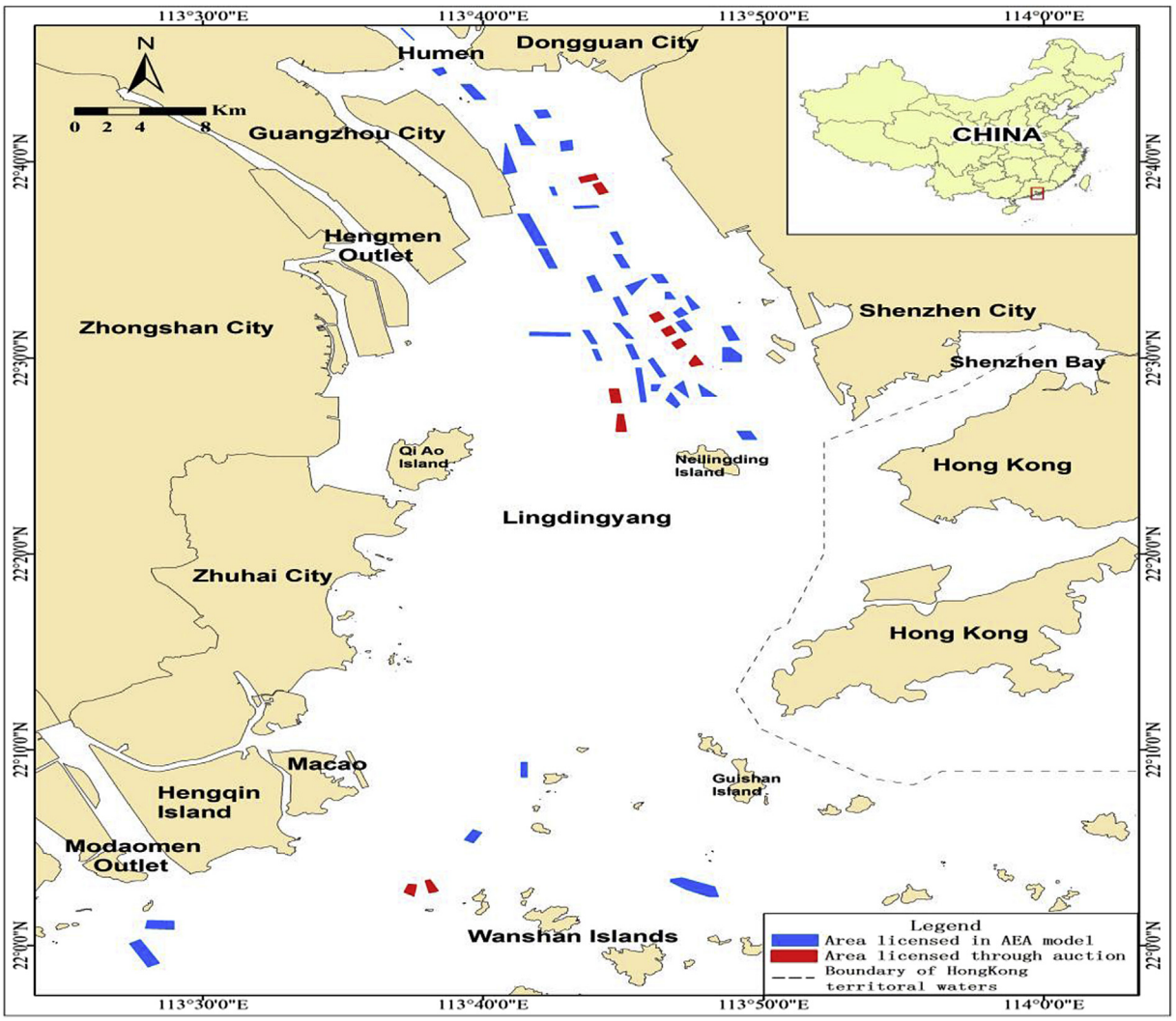

Fig. 1. Location of licensed mining areas in the Pearl River estuary waters.

2.2. Current management system of sand mining

Administrative system is crucial for coastal zone management, and an effective system is beneficial for efficient marine sand resource management. The current ocean management is under five levels of government (state, provincial/municipal, city, county, and town) and top-down management is still the main management approach in China (Wang, 2012). Over the last decades, the Chinese government has developed many legislations and regulations for ocean and coastal zone management. Most of the coastal provincial and municipal governments were empowered to issue regulations, and all laws were sectoral legislations issued by different sectoral agencies. The power to regulate marine sand exploitation in the Pearl River estuary was decentralized to different administrative departments according to these national and local regulations. Important government agencies that have direct responsibilities for marine sand exploitation management at the national level are the SOA and the Ministry of Transportation (executed by the Guangdong Maritime Safety Administration, GMSA). There is one provincial government (Government of Guangdong Province, GGP) that administers the Pearl River estuary, and three provincial departments, namely, the AOFGP, the Water Resources Department of the Guangdong Province (WRDG) and the Department of Land and Resources of Guangdong Province (DLRG).[2] Legal authorities and related responsibilities for marine sand exploitation are summarized in Table 2.

In order to exploit marine sand in the Pearl River estuary, the mining company should get the following permissions from the concerned administrative departments according to the relevant regulations (Yao and Li, 2009):

(1) a sea-area-use license for sand mining from the SOA;
(2) a surface and underwater operation certificate from the GMSA;
(3) a river sand mining license from the WRDG;
(4) an exploration and mining license from the DLRG.

At present, the AEA is the main management approach for resource allocation, which means that anyone who wants to mine in the Pearl River estuary waters must submit certain required application documents to competent departments. These documents include a marine environmental impact assessment (MEIA)

[2] The DLRG has not exercise the responsibility of marine sand management because it does not have the resources, such as manpower and vessels, for marine supervisory enforcement.

Table 1
Marine sand dredging statistics in the Pearl River estuary waters.

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Number of mining firms	6	6	6	4	4	10	8	8	16	18
Area licensed (hm^2)	2755	2635	844.70	675	1206	1846	640	659.80	797.70	2065
Estimated quantity of mining (million m^3)	48.00	28.05	17.38	12.30	13.80	27.20	10.70	11.50	12.90	30.50

Source: Data from the national sea-area-use management system of the SOA (unpub. data), 2011.

report to the SOA, a navigation impact report to the GMSA and a flooding impact assessment report to the WRDG. The examination and review process will be initiated if these application documents meet the requirements, but each functional department makes a decision only based on its own responsibilities. They permit mining by considering the size of the mining area, the capacity of facilities and equipments, the sailing plan, and the location of the mining area, etc. In general, mining in certain areas such as habitat reserves, nature reserves, fishery resource reserves, and navigable waterways should not be permitted, and the period for mining should not exceed two years.

2.3. Main problems of current management system

The current marine management system was established in the 1960s under the traditional natural resource development in the planned economy of China. Facing increasing demand of marine sand as well as more and more impacts on ecological environment caused by chaotic, excessive and illegal sand mining activities in the Pearl River estuary, the system is no longer suitable for modern development of sand mining industry. The main problems of the current marine sand management are discussed below.

2.3.1. Unclear responsibilities and lack of coordination among agencies

As noted above, several different administrative agencies are authorized to regulate marine sand mining activities in the Pearl River estuary. They may make their own policies, plans and regulations independently, and some of these policies may be different or even conflict. The overlapping jurisdictions for marine sand exploitation activities resulted in various agencies doing similar jobs, thus, conflicts were inevitable. Conflicts between the SOA and the WRDG are especially unavoidable because there is no clear boundary between ocean and river in the estuary. Although the SOA is regarded as the principal administrative agency to regulate sand mining activities, it does not have the authority to coordinate all involved sectors. It is due to the fact that these sectors are under the jurisdictions of different agencies in China's administrative hierarchy. At present, the SOA is only in charge of marine environment protection and sea-area-use management. Even in marine environment protection, the SOA does not have the supreme authority because the seaports' environment protection is presently under the charge of the GMSA. All departments make and implement laws separately, and their strength is dispersed (Ding, 2003). Management by separate administrative agencies, the lack of a leading agency and overlapping jurisdictions have led to inefficient administration, high administrative costs and coordination difficulties.

To correct the drawbacks of sector-based management, the administrative agencies' responsibilities should be clear and a leading agency should be appointed among the involved agencies. A coordination mechanism should be built to deal with conflicts, resolve overlapping responsibilities and increase cooperations on sand mining affairs.

2.3.2. Inefficient resource allocation approach

The AEA approach plays an important role in regulating marine resource use and ocean management. According to the current legal framework, a mining plan must be recognized and accepted by the DLRG, WRDG and GMSA. To meet the management requirements, the reasonableness of the mining quantity, impacts on flood control and navigation safety would be considered by each functional department. And they would make a decision only based on their own responsibilities. Unless approved by all the competent departments, nobody can commence a marine sand exploitation in the estuary. A major disadvantage of the approach is the lack of competition among the applicants because the government choice decides the winner of a bid, instead of the market choice (Wang,

Table 2
Legal authorities and responsibilities of government agencies associated with sand exploitation.

Category	Management functions	Legislations and rules	Affiliated sea supervision enforcement
State Oceanic Administration	Sea-area-use management Prevention of pollution and protection of marine environment	Sea Area Use Management Law Marine Environmental Protection Law	China Marine Surveillance
Guangdong Maritime Safety Administration	Prevention of marine traffic accidents and ship source pollution	Maritime Safety Law Ship Source Pollution Regulation	China Maritime Safety Administration
Government of Guangdong Province	Coordination in provincial economic and social development management, including marine affairs	The Constitution of the People's Republic of China	–
Administration of Ocean and Fisheries of Guangdong Province	Sea area use management of Guangdong Province Protection of fishery resources	Sea Area Use Management Regulations of Guangdong Province The Fisheries Law	China Marine Surveillance
Water Resources Department of Guangdong Province	Manages the exploitation and conservation of river sand resources Prevents sand mining which may affects flood control	River Sand Mining Regulation of Guangdong Province Guangdong Province estuary beaches management regulations	China Water Administration
Department of Land and Resources of Guangdong Province	Manages the prospecting, exploitation and conservation of marine sand resources	Mineral Resources Law Provisions on the Administration of Collection of the Mineral Resources compensation	None

2003). The government choice is unlikely to realize the maximum resource value, resulting in price distortion, excess supply, misallocation of resources, and ecological damage (Chen, 2012).

In addition, the AEA approach is often influenced by informal power of personal network (*guanxi*), because administrators usually have a large amount of discretion and their decisions can be made based on their personal likes or dislikes. *Guanxi* is a Chinese phrase for a set of interpersonal relationships that facilitate the exchange of favors to achieve mutual benefits, and represents a network of connections between businessmen and government officials through which money and power are exchanged (Gu and Wong, 2008; Maren, 2005). Some marine sand mining enterprises can obtain "special treatment," e.g., a lower qualification threshold or a special privilege from government officials, or being exempted from fines for pollution or illegal sand mining activities. As a result of potential corruption linked to *guanxi*, the policies and laws related to marine sand exploitation or protection may not always be legitimately implemented.

2.3.3. Neglecting the cost of environment damage

After the sea-area-use law was issued in 2001, sea space is no longer a free resource. A mining company must pay a sea-area-use fee to the government before commencing marine sand exploitation. The current standard fee, which was officially established by the Ministry of Finance of China in 2007, is 45 000 CNY per hectare and does not consider the location or the quantity of the sand to be mined. Until recently, the price of marine sand only includes the sea-area-use fee, the cost of mining at sea, sea transportation, unloading at berth, and land transportation, etc., while the price of river sand includes administrative expenses, the cost of mining, river transportation, unloading at berth, land transportation, and mineral resources compensation,[3] etc. Also, the sand washing cost is not required to be considered by river sand consumers, so the price of river sand is higher than that of marine sand (Table 3). Marine sand has been supplied at a price so low that has made the Pearl River Delta one of the largest per capita consumption of marine sand in the world.

The hydrology and morphology of the Pearl River estuary water system has been altered by uncontrolled sand exploitation over the last 30 years. Extensive and unplanned marine sand mining has reduced riverbed height of the main channels of the Pearl River, which has profound impacts on the coastal environment. Saltwater intrusion is one of the most notable events that affect the water supply for about 15 million residents living in the coastal region of the estuary during the dry season almost every year. At present, saltwater intrusion occurs in 10–20 km more upstream areas than the natural saltwater intrusion in the 1980s. The saltwater intrusion may last for half a year in dry seasons, and water shortage has been a local issue in the areas surrounding the estuary. Uneven sand mining also increased the slope and instability of the seawalls, which poses a big threat to nearby residents. In July 2005, two incidents of broken dikes occurred at the site nearest from where most marine sand had been mined. The incidents caused more than 10 buildings to collapse, and nearly 1000 people from 300 families had to be relocated. Studies based on long-term field surveys supported the relation between the incidents and sand mining (Luo et al., 2007; Zhang, 2003).

Sand mining can affect the marine habitat adversely by removing the sand and its plume, which raises mortality of fisheries and causes damages to ecosystem. Until now, there is no report on the effects of sand mining on fishery based on a long-term monitoring in the Pearl River estuary, except for a study that analyzed the changes caused by navigational channel dredging based on investigation of fishery resources, which are similar to the changes caused by sand mining. According to the study (Wang and Zhang, 2001), the environmental protection measures had been taken, but the number of fishery resources changed obviously before and during the dredging period (Table 4).

Mining of marine sand has resulted in marine environmental externalities. However, these external costs have not been included in the price of marine sand and not been internalized by mining companies. The fixed-price system devalues marine resources and leads to the loss of a state-owned natural resource asset. Furthermore, environmental damages caused by intensive sand mining activities cannot be restored due to insufficient funds. Let the mining firms internalize the external costs would contribute to increasing the price and decreasing the demand of marine sand.

Table 3
Annual average price comparison of marine sand and river sand in the areas surrounding the estuary (units: CNY/cubic meter).

Year	2000	2003	2006	2008	2009	2010	2011	2012	2013
Annual average price of marine sand	5.50	6.20	14.40	19.00	21.00	22.80	24.50	26.00	45.00
Annual average price of river sand	42.00	47.00	50.00	58.80	60.00	65.00	91.30	95.00	121.70

Sources: Data from the Shenzhen construction project cost management station (2013) and MEIA reports.

[3] The Provisions on the Administration of Collection of the Mineral Resources Compensation in 1997 stipulates that mining firms must pay royalty of 2% of the sales amount of sand to government who permit mining, but it is not enforced on marine sand.

3. Responses to marine sand management problems

In response to the environmental damages caused by sand mining, the SOA decided to develop a new management approach for sustainable exploitation of marine sand. Since the year 2007, although there were more than 50 sea-area-use applications for sand mining in the Pearl River estuary waters, permits were consciously reduced and supervision of law enforcement was intensified to prevent illegal sand mining activities. Then, the AOFGP was authorized to initiate a pilot scheme of using market-based approach to allocate sand mining sea-area-use rights in the Pearl River estuary. The objectives of the pilot scheme are:

(1) to establish a predominantly market-based approach to the allocation of sand mining to maximize the value of marine sand;
(2) to establish cooperative partnerships with other competent departments for marine sand management via the pilot scheme;
(3) to prohibit nearshore sand mining to minimize environmental damage;
(4) to gather valuable experience and identify feasible methods for application in all China's coastal areas.

3.1. Leading agency appointment

The reduction of sea-area-use permits intensified the demand of sand resource in the Pearl River Delta. This situation created a challenge for the GGP, which has the responsibility to support massive ongoing infrastructure projects. As requested by the SOA,

Table 4
Changes in number of fishery resources before and during the dredging engineering.

	Density of fishery resources (before the dredging)				Density of fishery resources (during the dredging)			
	1997.5	1997.9	1998.5	1998.9	1999.5	1999.9	2000.5	2000.9
Benthos (mg/m^2)	21.80	20.00	20.48	19.80	10.30	8.44	13.80	10.30
Young fish (ind. per net)	510.00	480.00	520.00	456.00	512.00	455.00	476.00	448.00
Spawn (ind. per net)	145.00	6.00	150.00	6.00	165.00	5.00	170.00	7.00

the GGP organized several joint meetings of the concerned departments to coordinate marine sand mining management. After rounds of bilateral and multilateral talks, both formal and informal, the officials who have administrative responsibilities have fully realized the management challenges and reached a shared vision of working together for common benefits. To enhance management efficiency, the involved agencies all agreed to clearly define their responsibilities to reduce and avoid contradictions by making provisions based on the current legal framework. Finally, the Memorandum of Understanding on the Pearl River estuary Management was signed in 2008, which includes the following four main points.

(1) The Pearl River estuary is a "joint management region," in which sand mining activities must meet administrative requirements of all the competent departments. Cooperation should be strengthened towards the goal of managing marine sand sustainably.
(2) In view of the capability and historical experience of law enforcement, the AOFGP was appointed as the leading agency for sand mining management.
(3) For mining firms, the only certification required to perform sand mining activities in the Pearl River estuary waters (including the "joint management region") is the sea-area-use license. Before issuing the license, the AOFGP should take into account the requirements of other functional departments.
(4) Cooperation in law enforcement should be strengthened to prevent illegal sand mining activities.

3.2. Preparatory work for the pilot scheme

Since the start of 2008, a research team consisting of academics, public officials and industrial consultants was organized by the AOFGP. The research team comprehensively investigated the sand dredging industry, including the reserves and distribution, annual supply and demand, extraction and processing technology, and current management issues of marine sand in the estuary. The investigation revealed that there were 18 licensed mining areas (with the total area of 2060 hm^2) in the estuary waters by May 2010, and 20 sea-area-use applications from 17 mining firms had been accepted by the SOA and would be examined with the AEA approach. The research team also carried out studies on potential cooperation models of the competent departments, compensation standards for environment damages, auction models and rules, and calculation methods of starting price for sea-area-use rights.

Taking into account of resource distribution, marine functional zoning, supply and demand forecast, exploration technology, environmental protection, and economic analysis, a Sea Area Use Plan for Sand Mining in the Pearl River was developed by the research team. The estuary was divided into minable areas and mining -forbidden areas, and an annual allowed quantity of mineable sand was proposed. Based on the plan, six areas were designated as the "expected mining areas," and corresponding mining plans including location, minable quantity, the number of dredgers and carriers, navigation plan, and mining technology were made by the research team in 2010. This preparatory work served as a solid foundation for the pilot scheme.

3.3. Making market rules

Although a "socialist market economy" has been in operation in China since 1993, many government officials are not sure how to utilize market rules in management of natural resources. The research team suggested that government actions must be regulated to promote healthy development of the sea-area-use market by establishing a transparent and standardized auction process, regulating the market and strengthening the supervision of transactions. With the assistance of the research team, a set of market rules were produced and issued by the AOFGP. First, the terms, limitations and conditions on sand mining sea-area-use market access had been issued. Mining firms that apply for sea-area-use permits are required to have independent legal personality, own professional sand mining equipments and have no law-breaching records in the three years prior to the application. Second, transaction regulations including auction rules and programs, terms of payment, rights and obligations of bidders and normative documents including model application forms, letter of authorization, sales confirmation, and contracts were produced to regulate the entire transaction. All of the rules mentioned above were determined by group discussion (the research team and relevant AOFGP members of staff), and then announced to the public. The whole transaction process must be operated in accordance with these rules. When a transaction is completed, the transaction documents are put on file for future reference and investigation.

The values of the market rules include unifying qualification threshold, regulating market behavior, standardizing operative procedures, and establishing a competitive market order. Based on these rules, an open, rule-based, equitable and standardized market allocation system was established. Establishing a standardized transparent auction process is of great significance for healthy development of the sea-area-use market.

3.4. Establishing an online trading platform

At the request of the AOFGP, an independent online trading platform was established by a third party—the Guangdong Public Resource Trading Center (GPRTC)—to carry out an online auction for determining the price of sea-area-use rights. Its main functions are to collect or release transaction information, organize qualification examination, provide counseling services, and put online transactions into practice according to the market rules made by the AOFGP. It can operate independently without government interference. Through the trading platform, a new management mechanism was established based on the clear definition of responsibilities, that is, the AOFGP is responsible for making market rules and auction plans, the GPRTC is responsible for online auction in accordance with the market rules and the state notary organs is responsible for supervision. The separation of rules making, implementation and supervision ensures that the transactions are conducted openly, honestly and fairly.

The independent and transparent online trading platform of sand mining rights is essential for a competitive market. The relationship among the administrations and the mining firms is now rationalized because the market rules replace the government choice. It can maximize the economical value of marine sand as well as reduce the influence of informal power. In addition, selecting a winning bidder through a standardized transparent allocation system can win the support of other agencies for the final outcome and encourage further cooperation.

3.5. Developing a cooperative mechanism

From the above discussion, it can be seen that sector-based management conducted by different departments has many drawbacks. The research team recognized such drawbacks and the need for a new management arrangement based on current legal responsibilities. As a result, a cooperative mechanism was developed to involve all competent agencies in the management process, through which to excise their functions. Combined with a redesigned management procedure (Fig. 2), a variety of participation pathways was created in order to encourage negotiation and discussion on marine sand management affairs, as described below.

(1) Official documentation system: The AOFGP shall ask the other competent departments for their views on site selection for sand mining and consult them for solutions via the official documentation system; the same goes for the auction plan. The working relationship between the AOFGP and the GPRTC was also established through this system to standardize and restrain the operation of transaction.
(2) MEIA review conference: To meet the other departments' management requirements, the MEIA system was improved. The reasonableness of the mining quantity and the impacts on flood control and navigation safety of the mining plan must be analyzed in the MEIA reports. The AOFGP shall confer with the departmental representatives on matters of their concerns at the MEIA review conference, and the mining plan will be adjusted until consensus is achieved.
(3) Regular and irregular reporting systems: To prevent illegal sand mining activities, regular and irregular reporting systems were established among the involved agencies to ensure excellent communication. Once any mining activity is found inconsistent with the agreed mining plan, the corresponding functional department will be informed through the systems to deal with the violators.

An important outcome of this approach is that different sand mining management agencies are well connected now. The interchange of views between the relevant departments is usually a time-consuming process; but once a consensus is reached, the implementation of the mining plan could proceed smoothly. This not only alleviates conflicts and increases mutual understandings on respective responsibilities but also enhances efficiency of law enforcement.

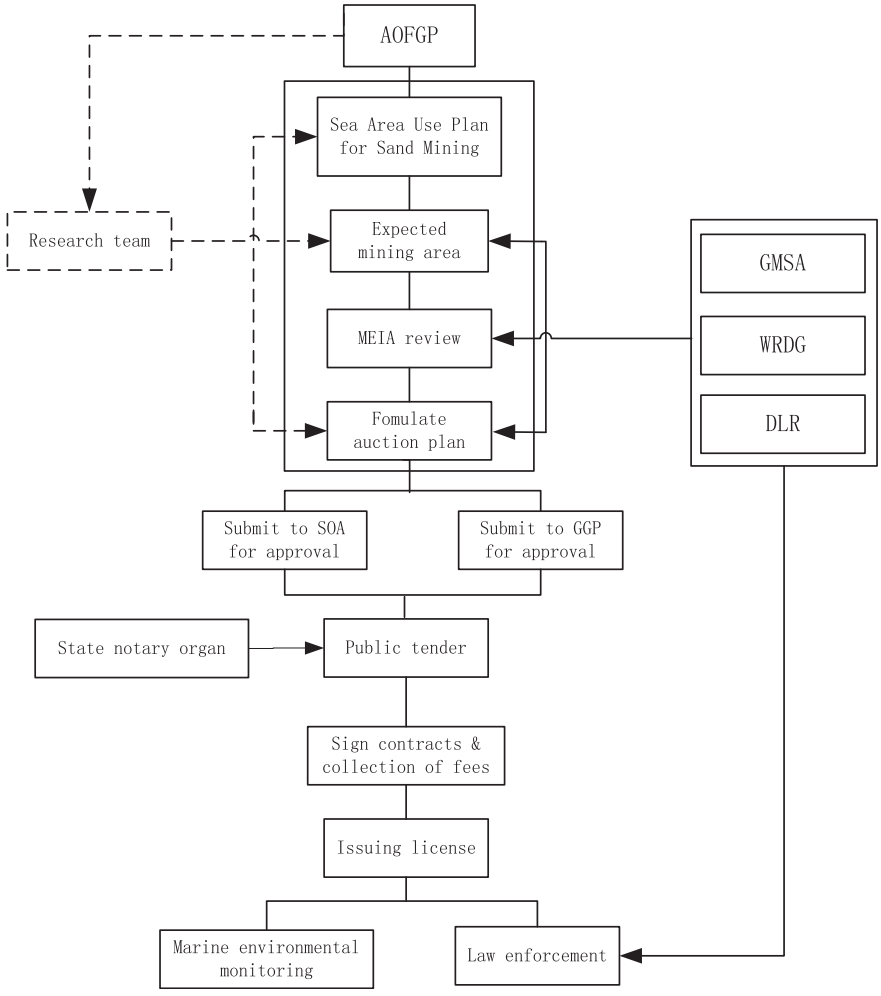

Fig. 2. Operating procedure of marine sand management.

3.6. Achievements and inadequacies of the pilot scheme

Following a long preparation and discussion, the first auction plan of sea-area-use rights for sand mining was formulated and submitted to the SOA and the GGP in June 2010. It was soon officially approved and announced to the public. The auction plan included:

(1) location, size and minable quantity of the designated area;
(2) suggested period of mining (not to exceed two years);
(3) date, time and place for bidding, starting price, qualification of a bidder, and model forms of contract;
(4) other relevant items for applying for the bid.

From June 26, 2010 to August 26, 2011, the rights of 10 "expected mining areas" (the total area of 597 hm^2 with the marine sand of approximate 20.9×10^6 m^3) were sold via open bidding. The bid price could not be lower than the starting price, which includes the fees for the use of sea areas, resource and environmental costs, MEIA costs, prospecting and mapping costs, with the right to mine being awarded to the highest bidder. This approach succeeded in auctioning off sand mining sea-area-use rights at 11.8 to 14.5 times the price of the AEA approach (Table 5). Although the auctioned areas are only about 30% of the total licensed mining areas in the estuary waters, the market price of marine sand nearly doubled in 2013 compared to that in 2010. Due to the increased price of marine sand, some construction companies began to seek alternative materials for their projects. For example, the reuse of dredged mud, which used to be considered as a waste, has increased significantly.

By facilitating the concerned departments more directly in the pilot scheme, the representatives are coming to a new appreciation of the problems of marine sand management. The transition from AEA to market-based approach not only realizes the maximum resource value but also reduces the potential of regulatory capture, because the allocation process is transparent. Mining companies are now motivated to optimize mining technologies, update equipments and reduce production costs rather than pursuing special treatment from government officials. This will be helpful to the development of the dredging industry. The pilot scheme has also created a coordinated mechanism for departments to discuss matters of mutual concern. Mutual trust and cooperation are growing among the involved agencies. In addition, ongoing institutional adjustments are taking place. For example, the national government plans to establish a centralized and integrated ocean bureau, named the National Ocean Council of China, which will be superior to all other marine sectors. Its main responsibilities will be to deal with conflicts, resolve overlapping responsibilities and promote cooperations among various departments on important marine affairs of the state. This will also unify the existing sea supervision enforcement forces. Surveillance to prohibit illegal sand mining will be the responsibility of the China Coast Guard, which is an agency under the SOA.

There are some ongoing problems. One is the failure in prohibiting nearshore sand mining in the Pearl River estuary, because most of the dredging vessels are small inland boats that cannot operate in rough conditions of the outer estuary. As a result, it is not feasible to designate a mining area in the outer part of the estuary. So, the mining areas have to be designated as far from the coastline as possible, but still within 10 nautical miles from the coastline. Another potential problem would be to improve the auction rules from "the highest bidder wins" to "the bidder who has the best combination of multiple advantages wins" (e.g., advanced dredging equipments, high resource utilization rates and low generation of pollutants, etc.). The AOFGP plans to achieve the goal of mining in the outer part of the estuary in the next 5–10 years.

The attempt to improve marine sand management in the Pearl River estuary since 2010 has been a success and yielded valuable experience for nationwide application (Cai et al., 2012). In January 2013, the AEA approach to allocate sand mining sea-area-use rights was officially stopped and the market-based approach based on the pilot scheme was applied in all coastal areas by the SOA.

4. Conclusions

Marine sand is a mineral resource of increasing importance for cities around the Pearl River estuary. The growing demand for sand, and excessive and illegal sand mining activities raised serious challenges to efficient resource use and environment protection in the estuary. In order to develop and implement a new management approach, a pilot scheme was initiated by the relevant departments. Some conclusions are provided here.

In the Pearl River estuary, three significant changes in marine sand management have occurred. First, using a market-based approach instead of AEA to allocate natural resources not only maximized the resource value but also helped to reduce the potential of regulatory capture. It also encouraged people to seek alternative construction materials and promotes the development of sand mining industry. The administrative authorization by the SOA is the premise upon which the AOFGP is able to implement the scheme at the provincial level. Second, the signing of the Memorandum of Understanding in 2008 provided an important institutional support for cooperation management through the appointment of a leading agency and clear definition of administrative responsibilities. Third, the AOFGP has developed a cooperative approach to complement the more conventional, sector-based management model through improving the MEIA, creating participation pathways and re-designing management procedure. Adoption of this approach is a necessary improvement compared to the previous management model. The administrative authorization, institutional support and approach improvement are the enabling factors that contributed to the success of the pilot scheme. With these factors in place, the following elements are essential for a market-based approach to manage marine sand efficiently.

A clearly defined exchange object makes it possible to establish a regular and orderly marine sand allocation market. Among all of the concerned jurisdictions, taking the sea-area-use rights as the sole exchange object is critical for the implementation of the market-based approach. With the institutional arrangement, a multi-seller practice for the marine sand has been eliminated in the estuary.

Independent third-party trade platform and standardized market rules are essential for a trade market to allocate the resource

Table 5
Price comparison for sea-area-use rights using AEA and auction.

Date of listing for trading	Number of mining areas for auction	Sea use area for sand mining (hm^2)	Minable quantity (million m^3)	Auction price (million CNY)	AEA price (million CNY)
June 26–30,2010	1	49.58	1.73	26.40	2.23
August 23–27,2010	5	315.92	11.52	187.30	14.22
August 23–26,2011	4	231.25	7.66	150.40	10.41
Total	10	596.75	20.91	364.10	26.86

according to market principles. The establishment of the platform not only provides an institutional climate for operation of market mechanism but also helps to reduce the potential of regulatory capture. Combined with the market rules, an open, rule-based, equitable and standardized market allocation system has been established.

Making rational goals for the resource management, and consistence with legislative framework would contribute to a good initiation of marketization. Careful integration of market mechanism, cooperation approach and legal control, balancing environmental protection goals and industry development level, and considering socioeconomic demands is required for the implement of the market-based approach.

Providing cooperation mechanism for involved agencies participation in the process of marketization can win their supports for the final outcome. Using market mechanism to allocate sand resource needs to address many issues caused by sectoral management model. Any unresolved obstacle encountered could have an impact on the approach. Facilitating the concerned agencies participation in the process helps to identify these obstacles and build broad-based supports.

The recent market-oriented allocation of sand mining sea-area-use rights in the Pearl River estuary provides a successful reference for marine sand management elsewhere in China. The model of marine sand management has shifted from the sectoral management model based on AEA to a cooperation management and market price approach. The market-based approach to allocate marine sand in China is still at its initial stage, and continuous efforts are needed for its improvement and success. We believe that the experience acquired in the Pearl River estuary will be useful for other coastal regions beyond China.

Author contribution

In this paper:M. Zhao and D. Yang designed the paper and analyzed the data; P. Wang and P. Shi contributed to collecting materials/paper revision; M. Zhao wrote the paper.

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